

# BOTULINUM TOXIN THERAPY FOR SKIN DISORDERS

by

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## BACKGROUND

The present invention relates to methods for treating skin disorders.  
10 In particular the present invention relates to methods for treating skin disorders by administration of a Clostridial neurotoxin to a patient.

### Skin Disorders

The skin (synonymously the cutis) is a protective membrane which  
15 covers the body and is composed of several layers including the epidermis and the cornium. A skin disorder is an anomaly or an abnormal skin growth and can appear at any cutis location, such as on a hand, foot or face of a patient. Some skin disorders are more prevalent at pressure, wear or weight bearing locations, such as on the feet. A  
20 skin disorder can be a wart, bunion, callus, corn, ulcer, neuroma, hammertoe, dermatofibroma, keloid, mole (such as a typical mole or dysplastic nevi), granuloma (such as a pyogenic granuloma) and a keratose (such as a seborrheic keratose).

25 A bunion is a localized swelling at either the medial or dorsal aspect of the first metatarsophalangeal joint of the foot and can be caused by an inflamed bursa. A bursa is a closed fluid filled sac that can form in an area subject to friction. A bunion can be due to hallux valgus which is a deviation of the tip of the big toe toward the outside of the foot. This can  
30 cause the first metatarsal and the big toe to form an aberrant leftward angle. A bunion can then develop in response to the pressure from a tight fitting shoe at the point of this angle.

A callus is a protective cutis pad made up of a thickened upper layer of skin which forms due to repeated rubbing of the skin at that location. A corn is a small callus which develops on the top of the toes due to pressure or rubbing against shoes or other toes. A corn can also develop due to a hammertoe condition which is an abnormal contraction or buckling of the toe because of a partial or complete dislocation of one of the joints of the toe or the joint where the toe joins with the rest of the foot. As the toe becomes deformed, it can rub against a shoe and the resulting irritation can cause the build up more and thicker skin (a corn) as a protective response at that cutis location.

An ulcer is a slow healing skin wound. A stage one ulcer is characterized by reddening of skin over a bony area. The redness on the skin does not go away when the pressure is relieved. A stage two ulcer is characterized by a blister, peeling or cracked skin. There is a partial thickness skin loss involving the top two layers of the skin. A stage three ulcer exhibits broken skin and sometimes a bloody drainage. There is a full thickness skin loss involving subcutaneous tissue. Finally, a stage four ulcer is characterized by a break in the skin involving skin, muscle, tendon and bone and is often associated with a bone infection (osteomyelitis). Ulcers can be debilitating and painful.

Warts are non-cancerous skin growths caused by infection in the top layer of the skin by a papillomavirus. Warts are usually skin-colored and may feel rough to the touch, but they can be dark, flat and smooth. There are several different kinds of warts including common warts, foot (plantar) warts and flat warts. A plantar wart is a small skin lesion that resembles a callus and is found on the bottom of the foot or toes.

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A neuroma is a swelling or scarring of a small nerve that connects to two toes and provides sensation to these toes. Symptoms of a neuroma

can include pain or numbness, usually affecting the third and fourth. Neuromas frequently start as a numbness or tenderness in the ball of the foot.

5        Current therapies for skin disorders includes use of various topical and systemic pharmaceuticals and/or surgery to excise the disorder. Pharmaceuticals typically have unwanted side effects and there can unfortunately be a significant reoccurrence of the skin disorder (regrowth) after surgery, as well as the possibly of infection.

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### Botulinum Toxin

The genus Clostridium has more than one hundred and twenty seven species, grouped according to their morphology and functions. The anaerobic, gram positive bacterium Clostridium botulinum produces a  
15        potent polypeptide neurotoxin, botulinum toxin, which causes a neuromuscular illness in humans and animals referred to as botulism. The spores of Clostridium botulinum are found in soil and can grow in improperly sterilized and sealed food containers of home based canneries, which are the cause of many of the cases of botulism. The  
20        effects of botulism typically appear 18 to 36 hours after eating the foodstuffs infected with a Clostridium botulinum culture or spores. The botulinum toxin can apparently pass unattenuated through the lining of the gut and attack peripheral motor neurons. Symptoms of botulinum toxin intoxication can progress from difficulty walking, swallowing, and  
25        speaking to paralysis of the respiratory muscles and death.

Botulinum toxin type A is the most lethal natural biological agent known to man. About 50 picograms of a commercially available botulinum toxin type A (purified neurotoxin complex)<sup>1</sup> is a LD<sub>50</sub> in mice  
30        (i.e. 1 unit). One unit of BOTOX® contains about 50 picograms (about 56 attomoles) of botulinum toxin type A complex. Interestingly, on a

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<sup>1</sup> Available from Allergan, Inc., of Irvine, California under the tradename BOTOX® in 100 unit vials)

molar basis, botulinum toxin type A is about 1.8 billion times more lethal than diphtheria, about 600 million times more lethal than sodium cyanide, about 30 million times more lethal than cobra toxin and about 12 million times more lethal than cholera. Singh, *Critical Aspects of*  
5 *Bacterial Protein Toxins*, pages 63-84 (chapter 4) of *Natural Toxins II*, edited by B.R. Singh et al., Plenum Press, New York (1976) (where the stated LD50 of botulinum toxin type A of 0.3 ng equals 1 U is corrected for the fact that about 0.05 ng of BOTOX® equals 1 unit). One unit (U) of botulinum toxin is defined as the LD50 upon intraperitoneal injection  
10 into female Swiss Webster mice weighing 18 to 20 grams each.

Seven generally immunologically distinct botulinum neurotoxins have been characterized, these being respectively botulinum neurotoxin serotypes A, B, C1, D, E, F and G each of which is distinguished by  
15 neutralization with type-specific antibodies. The different serotypes of botulinum toxin vary in the animal species that they affect and in the severity and duration of the paralysis they evoke. For example, it has been determined that botulinum toxin type A is 500 times more potent, as measured by the rate of paralysis produced in the rat, than is  
20 botulinum toxin type B. Additionally, botulinum toxin type B has been determined to be non-toxic in primates at a dose of 480 U/kg which is about 12 times the primate LD50 for botulinum toxin type A. Moyer E et al., *Botulinum Toxin Type B: Experimental and Clinical Experience*, being chapter 6, pages 71-85 of "Therapy With Botulinum Toxin", edited  
25 by Jankovic, J. et al. (1994), Marcel Dekker, Inc. Botulinum toxin apparently binds with high affinity to cholinergic motor neurons, is translocated into the neuron and blocks the release of acetylcholine. Additional uptake can take place through low affinity receptors, as well as by phagocytosis and pinocytosis.

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Regardless of serotype, the molecular mechanism of toxin intoxication appears to be similar and to involve at least three steps or

stages. In the first step of the process, the toxin binds to the presynaptic membrane of the target neuron through a specific interaction between the heavy chain, H chain, and a cell surface receptor; the receptor is thought to be different for each type of botulinum toxin and for tetanus toxin. The carboxyl end segment of the H chain, HC, appears to be important for targeting of the toxin to the cell surface.

In the second step, the toxin crosses the plasma membrane of the poisoned cell. The toxin is first engulfed by the cell through receptor-mediated endocytosis, and an endosome containing the toxin is formed. The toxin then escapes the endosome into the cytoplasm of the cell. This step is thought to be mediated by the amino end segment of the H chain, HN, which triggers a conformational change of the toxin in response to a pH of about 5.5 or lower. Endosomes are known to possess a proton pump which decreases intra-endosomal pH. The conformational shift exposes hydrophobic residues in the toxin, which permits the toxin to embed itself in the endosomal membrane. The toxin (or at a minimum the light chain) then translocates through the endosomal membrane into the cytoplasm.

The last step of the mechanism of botulinum toxin activity appears to involve reduction of the disulfide bond joining the heavy chain, H chain, and the light chain, L chain. The entire toxic activity of botulinum and tetanus toxins is contained in the L chain of the holotoxin; the L chain is a zinc ( $Zn^{++}$ ) endopeptidase which selectively cleaves proteins essential for recognition and docking of neurotransmitter-containing vesicles with the cytoplasmic surface of the plasma membrane, and fusion of the vesicles with the plasma membrane. Tetanus neurotoxin, botulinum toxin types B, D, F, and G cause degradation of synaptobrevin (also called vesicle-associated membrane protein (VAMP)), a synaptosomal membrane protein. Most of the VAMP present at the cytoplasmic surface of the synaptic vesicle is removed as

a result of any one of these cleavage events. Botulinum toxin serotype A and E cleave SNAP-25. Botulinum toxin serotype C1 was originally thought to cleave syntaxin, but was found to cleave syntaxin and SNAP-25. Each of the botulinum toxins specifically cleaves a different bond, except botulinum toxin type B (and tetanus toxin) which cleave the same bond. Each of these cleavages block the process of vesicle-membrane docking, thereby preventing exocytosis of vesicle content.

Botulinum toxins have been used in clinical settings for the treatment of neuromuscular disorders characterized by hyperactive skeletal muscles (i.e. motor disorders). In 1989 a botulinum toxin type A complex has been approved by the U.S. Food and Drug Administration for the treatment of blepharospasm, strabismus and hemifacial spasm. Subsequently, a botulinum toxin type A was also approved by the FDA for the treatment of cervical dystonia and for the treatment of glabellar lines, and a botulinum toxin type B was approved for the treatment of cervical dystonia. Non-type A botulinum toxin serotypes apparently have a lower potency and/or a shorter duration of activity as compared to botulinum toxin type A. Clinical effects of peripheral intramuscular botulinum toxin type A are usually seen within one week of injection. The typical duration of symptomatic relief from a single intramuscular injection of botulinum toxin type A averages about three months, although significantly longer periods of therapeutic activity have been reported.

Although all the botulinum toxins serotypes apparently inhibit release of the neurotransmitter acetylcholine at the neuromuscular junction, they do so by affecting different neurosecretory proteins and/or cleaving these proteins at different sites. For example, botulinum types A and E both cleave the 25 kiloDalton (kD) synaptosomal associated protein (SNAP-25), but they target different amino acid sequences within this protein. Botulinum toxin types B, D, F and G act on vesicle-associated

protein (VAMP, also called synaptobrevin), with each serotype cleaving the protein at a different site. Finally, botulinum toxin type C1 has been shown to cleave both syntaxin and SNAP-25. These differences in mechanism of action may affect the relative potency and/or duration of action of the various botulinum toxin serotypes. Apparently, a substrate for a botulinum toxin can be found in a variety of different cell types. See e.g. *Biochem J* 1;339 (pt 1):159-65:1999, and *Mov Disord*, 10(3):376:1995 (pancreatic islet B cells contains at least SNAP-25 and synaptobrevin).

The molecular weight of the botulinum toxin protein molecule, for all seven of the known botulinum toxin serotypes, is about 150 kD. Interestingly, the botulinum toxins are released by Clostridial bacterium as complexes comprising the 150 kD botulinum toxin protein molecule along with associated non-toxin proteins. Thus, the botulinum toxin type A complex can be produced by Clostridial bacterium as 900 kD, 500 kD and 300 kD forms. Botulinum toxin types B and C1 is apparently produced as only a 700 kD or 500 kD complex. Botulinum toxin type D is produced as both 300 kD and 500 kD complexes. Finally, botulinum toxin types E and F are produced as only approximately 300 kD complexes. The complexes (i.e. molecular weight greater than about 150 kD) are believed to contain a non-toxin hemagglutinin protein and a non-toxin and non-toxic nonhemagglutinin protein. These two non-toxin proteins (which along with the botulinum toxin molecule comprise the relevant neurotoxin complex) may act to provide stability against denaturation to the botulinum toxin molecule and protection against digestive acids when toxin is ingested. Additionally, it is possible that the larger (greater than about 150 kD molecular weight) botulinum toxin complexes may result in a slower rate of diffusion of the botulinum toxin away from a site of intramuscular injection of a botulinum toxin complex.

In vitro studies have indicated that botulinum toxin inhibits potassium cation induced release of both acetylcholine and norepinephrine from primary cell cultures of brainstem tissue. Additionally, it has been reported that botulinum toxin inhibits the evoked release of both glycine and glutamate in primary cultures of spinal cord neurons and that in brain synaptosome preparations botulinum toxin inhibits the release of each of the neurotransmitters acetylcholine, dopamine, norepinephrine (Habermann E., et al., *Tetanus Toxin and Botulinum A and C Neurotoxins Inhibit Noradrenaline Release From Cultured Mouse Brain*, J Neurochem 51(2);522-527:1988) CGRP, substance P and glutamate (Sanchez-Prieto, J., et al., *Botulinum Toxin A Blocks Glutamate Exocytosis From Guinea Pig Cerebral Cortical Synaptosomes*, Eur J. Biochem 165;675-681:1987.. Thus, when adequate concentrations are used, stimulus-evoked release of most neurotransmitters is blocked by botulinum toxin. See e.g. Pearce, L.B., *Pharmacologic Characterization of Botulinum Toxin For Basic Science and Medicine*, Toxicon 35(9);1373-1412 at 1393; Bigalke H., et al., *Botulinum A Neurotoxin Inhibits Non-Cholinergic Synaptic Transmission in Mouse Spinal Cord Neurons in Culture*, Brain Research 360;318-324:1985; Habermann E., *Inhibition by Tetanus and Botulinum A Toxin of the release of [3H]Noradrenaline and [3H]GABA From Rat Brain Homogenate*, Experientia 44;224-226:1988, Bigalke H., et al., *Tetanus Toxin and Botulinum A Toxin Inhibit Release and Uptake of Various Transmitters, as Studied with Particulate Preparations From Rat Brain and Spinal Cord*, Naunyn-Schmiedeberg's Arch Pharmacol 316;244-251:1981, and; Jankovic J. et al., *Therapy With Botulinum Toxin*, Marcel Dekker, Inc., (1994), page 5.

Botulinum toxin type A can be obtained by establishing and growing cultures of Clostridium botulinum in a fermenter and then harvesting and purifying the fermented mixture in accordance with known procedures. All the botulinum toxin serotypes are initially synthesized as inactive



single chain proteins which must be cleaved or nicked by proteases to become neuroactive. The bacterial strains that make botulinum toxin serotypes A and G possess endogenous proteases and serotypes A and G can therefore be recovered from bacterial cultures in

5 predominantly their active form. In contrast, botulinum toxin serotypes C1, D and E are synthesized by nonproteolytic strains and are therefore typically unactivated when recovered from culture. Serotypes B and F are produced by both proteolytic and nonproteolytic strains and therefore can be recovered in either the active or inactive form.

10 However, even the proteolytic strains that produce, for example, the botulinum toxin type B serotype only cleave a portion of the toxin produced. The exact proportion of nicked to unnicked molecules depends on the length of incubation and the temperature of the culture. Therefore, a certain percentage of any preparation of, for example, the

15 botulinum toxin type B toxin is likely to be inactive, possibly accounting for the known significantly lower potency of botulinum toxin type B as compared to botulinum toxin type A. The presence of inactive botulinum toxin molecules in a clinical preparation will contribute to the overall protein load of the preparation, which has been linked to increased

20 antigenicity, without contributing to its clinical efficacy. Additionally, it is known that botulinum toxin type B has, upon intramuscular injection, a shorter duration of activity and is also less potent than botulinum toxin type A at the same dose level.

25 High quality crystalline botulinum toxin type A can be produced from the Hall A strain of *Clostridium botulinum* with characteristics of  $\geq 3 \times 10^7$  U/mg, an A260/A278 of less than 0.60 and a distinct pattern of banding on gel electrophoresis. The known Shantz process can be used to obtain crystalline botulinum toxin type A, as set forth in Shantz,

30 E.J., et al, *Properties and use of Botulinum toxin and Other Microbial Neurotoxins in Medicine*, Microbiol Rev. 56;80-99:1992. Generally, the botulinum toxin type A complex can be isolated and purified from an

anaerobic fermentation by cultivating *Clostridium botulinum* type A in a suitable medium. The known process can also be used, upon separation out of the non-toxin proteins, to obtain pure botulinum toxins, such as for example: purified botulinum toxin type A with an  
5 approximately 150 kD molecular weight with a specific potency of 1-2 X 10<sup>8</sup> LD50 U/mg or greater; purified botulinum toxin type B with an approximately 156 kD molecular weight with a specific potency of 1-2 X 10<sup>8</sup> LD50 U/mg or greater, and; purified botulinum toxin type F with an approximately 155 kD molecular weight with a specific potency of 1-2 X  
10 10<sup>7</sup> LD50 U/mg or greater.

Botulinum toxins and/or botulinum toxin complexes can be obtained from List Biological Laboratories, Inc., Campbell, California; the Centre for Applied Microbiology and Research, Porton Down , U.K.; Wako  
15 (Osaka, Japan), Metabionics (Madison, Wisconsin) as well as from Sigma Chemicals of St Louis, Missouri. Pure botulinum toxin can also be used to prepare a pharmaceutical composition.

As with enzymes generally, the biological activities of the botulinum  
20 toxins (which are intracellular peptidases) is dependant, at least in part, upon their three dimensional conformation. Thus, botulinum toxin type A is detoxified by heat, various chemicals surface stretching and surface drying. Additionally, it is known that dilution of the toxin complex obtained by the known culturing, fermentation and purification to the  
25 much, much lower toxin concentrations used for pharmaceutical composition formulation results in rapid detoxification of the toxin unless a suitable stabilizing agent is present. Dilution of the toxin from milligram quantities to a solution containing nanograms per milliliter presents significant difficulties because of the rapid loss of specific  
30 toxicity upon such great dilution. Since the toxin may be used months or years after the toxin containing pharmaceutical composition is

formulated, the toxin can be stabilized with a stabilizing agent such as albumin and gelatin.

A commercially available botulinum toxin containing pharmaceutical composition is sold under the trademark BOTOX® (available from Allergan, Inc., of Irvine, California). BOTOX® consists of a purified botulinum toxin type A complex, albumin and sodium chloride packaged in sterile, vacuum-dried form. The botulinum toxin type A is made from a culture of the Hall strain of *Clostridium botulinum* grown in a medium containing N-Z amine and yeast extract. The botulinum toxin type A complex is purified from the culture solution by a series of acid precipitations to a crystalline complex consisting of the active high molecular weight toxin protein and an associated hemagglutinin protein. The crystalline complex is re-dissolved in a solution containing saline and albumin and sterile filtered (0.2 microns) prior to vacuum-drying. The vacuum-dried product is stored in a freezer at or below -5°C. BOTOX® can be reconstituted with sterile, non-preserved saline prior to intramuscular injection. Each vial of BOTOX® contains about 100 units (U) of *Clostridium botulinum* toxin type A purified neurotoxin complex, 0.5 milligrams of human serum albumin and 0.9 milligrams of sodium chloride in a sterile, vacuum-dried form without a preservative.

To reconstitute vacuum-dried BOTOX®, sterile normal saline without a preservative; (0.9% Sodium Chloride Injection) is used by drawing up the proper amount of diluent in the appropriate size syringe. Since BOTOX® may be denatured by bubbling or similar violent agitation, the diluent is gently injected into the vial. For sterility reasons BOTOX® is preferably administered within four hours after the vial is removed from the freezer and reconstituted. During these four hours, reconstituted BOTOX® can be stored in a refrigerator at about 2° C. to about 8°C. Reconstituted, refrigerated BOTOX® has been reported to retain its potency for at least about two weeks. *Neurology*, 48:249-53:1997.

It has been reported that botulinum toxin type A has been used in clinical settings as follows:

- 5 (1) about 75-125 units of BOTOX® per intramuscular injection (multiple muscles) to treat cervical dystonia;
- (2) 5-10 units of BOTOX® per intramuscular injection to treat glabellar lines (brow furrows) (5 units injected intramuscularly into the procerus muscle and 10 units injected intramuscularly into each corrugator supercilii muscle);
- 10 (3) about 30-80 units of BOTOX® to treat constipation by intrasphincter injection of the puborectalis muscle;
- (4) about 1-5 units per muscle of intramuscularly injected BOTOX® to treat blepharospasm by injecting the lateral pre-tarsal orbicularis oculi muscle of the upper lid and the lateral pre-tarsal orbicularis oculi of the  
15 lower lid.
- (5) to treat strabismus, extraocular muscles have been injected intramuscularly with between about 1-5 units of BOTOX®, the amount injected varying based upon both the size of the muscle to be injected and the extent of muscle paralysis desired (i.e. amount of diopter  
20 correction desired).
- (6) to treat upper limb spasticity following stroke by intramuscular injections of BOTOX® into five different upper limb flexor muscles, as follows:
  - (a) flexor digitorum profundus: 7.5 U to 30 U
  - 25 (b) flexor digitorum sublimus: 7.5 U to 30 U
  - (c) flexor carpi ulnaris: 10 U to 40 U
  - (d) flexor carpi radialis: 15 U to 60 U
  - (e) biceps brachii: 50 U to 200 U. Each of the five indicated muscles has been injected at the same treatment session, so that the patient  
30 receives from 90 U to 360 U of upper limb flexor muscle BOTOX® by intramuscular injection at each treatment session.

(7) to treat migraine, pericranial injected (injected symmetrically into glabellar, frontalis and temporalis muscles) injection of 25 U of BOTOX® has showed significant benefit as a prophylactic treatment of migraine compared to vehicle as measured by decreased measures of migraine frequency, maximal severity, associated vomiting and acute medication use over the three month period following the 25 U injection.

It is known that botulinum toxin type A can have an efficacy for up to 12 months (*European J. Neurology* 6 (Supp 4): S111-S1150:1999), and in some circumstances for as long as 27 months, when used to treat glands, such as in the treatment of hyperhydrosis . See e.g. Bushara K., *Botulinum toxin and rhinorrhea*, *Otolaryngol Head Neck Surg* 1996;114(3):507, and *The Laryngoscope* 109:1344-1346:1999. However, the usual duration of an intramuscular injection of Botox® is typically about 3 to 4 months.

The success of botulinum toxin type A to treat a variety of clinical conditions has led to interest in other botulinum toxin serotypes. Two commercially available botulinum type A preparations for use in humans are BOTOX® available from Allergan, Inc., of Irvine, California, and Dysport® available from Beaufour Ipsen, Porton Down, England. A Botulinum toxin type B preparation (MyoBloc®) is available from Elan Pharmaceuticals of San Francisco, California.

In addition to having pharmacologic actions at the peripheral location, botulinum toxins may also have inhibitory effects in the central nervous system. Work by Weigand et al, *Nauny-Schmiedeberg's Arch. Pharmacol.* 1976; 292, 161-165, and Habermann, *Nauny-Schmiedeberg's Arch. Pharmacol.* 1974; 281, 47-56 showed that botulinum toxin is able to ascend to the spinal area by retrograde transport. As such, a botulinum toxin injected at a peripheral location,

for example intramuscularly, may be retrograde transported to the spinal cord.

U.S. Patent No. 5,989,545 discloses that a modified clostridial  
5 neurotoxin or fragment thereof, preferably a botulinum toxin, chemically conjugated or recombinantly fused to a particular targeting moiety can be used to treat pain by administration of the agent to the spinal cord.

A botulinum toxin has also been proposed for or has been used to  
10 treat otitis media of the ear (U.S. patent 5,766,605), inner ear disorders (U.S. patents 6,265, 379; 6,358,926), tension headache, (U.S. patent 6,458,365), migraine headache pain (U.S. patent 5,714,468), post-operative pain and visceral pain (U.S. patent 6,464,986), hair growth and hair retention (U.S. patent 6,299,893), psoriasis and dermatitis (U.S.  
15 patent 5,670,484), injured muscles (U.S. patent 6,423,319) various cancers (U.S. patents 6,139,845), smooth muscle disorders (U.S. patent 5,437,291), and neurogenic inflammation (U.S. patent 6,063,768). Controlled release toxin implants are known (see e.g. U.S. patents 6,306,423 and 6,312,708) as is transdermal botulinum toxin  
20 administration (U.S. patent application serial number 10/194805).

Additionally, a botulinum toxin may have an effect to reduce induced inflammatory pain in a rat formalin model. Aoki K., et al, *Mechanisms of the antinociceptive effect of subcutaneous Botox: Inhibition of peripheral  
25 and central nociceptive processing*, Cephalalgia 2003 Sep;23(7):649. Furthermore, it has been reported that botulinum toxin nerve blockage can cause a reduction of epidermal thickness. Li Y, et al., *Sensory and motor denervation influences epidermal thickness in rat foot glabrous skin*, Exp Neurol 1997;147:452-462 (see page 459). Finally, it is known  
30 to administer a botulinum toxin to the foot to treat excessive foot sweating (Katsambas A., et al., *Cutaneous diseases of the foot: Unapproved treatments*, Clin Dermatol 2002 Nov-Dec;20(6):689-699;

Sevim, S., et al., *Botulinum toxin-A therapy for palmar and plantar hyperhidrosis*, Acta Neurol Belg 2002 Dec;102(4):167-70), spastic toes (Suputtitada, A., *Local botulinum toxin type A injections in the treatment of spastic toes*, Am J Phys Med Rehabil 2002 Oct;81(10):770-5),  
5 idiopathic toe walking (Tacks, L., et al., *Idiopathic toe walking: Treatment with botulinum toxin A injection*, Dev Med Child Neurol 2002;44(Suppl 91):6), and foot dystonia (Rogers J., et al., *Injections of botulinum toxin A in foot dystonia*, Neurology 1993 Apr;43(4 Suppl 2)).

10 Tetanus toxin, as well as derivatives (i.e. with a non-native targeting moiety), fragments, hybrids and chimeras thereof can also have therapeutic utility. The tetanus toxin bears many similarities to the botulinum toxins. Thus, both the tetanus toxin and the botulinum toxins are polypeptides made by closely related species of Clostridium  
15 (*Clostridium tetani* and *Clostridium botulinum*, respectively). Additionally, both the tetanus toxin and the botulinum toxins are dichain proteins composed of a light chain (molecular weight about 50 kD) covalently bound by a single disulfide bond to a heavy chain (molecular weight about 100 kD). Hence, the molecular weight of tetanus toxin and  
20 of each of the seven botulinum toxins (non-complexed) is about 150 kD. Furthermore, for both the tetanus toxin and the botulinum toxins, the light chain bears the domain which exhibits intracellular biological (protease) activity, while the heavy chain comprises the receptor binding (immunogenic) and cell membrane translocational domains.

25 Further, both the tetanus toxin and the botulinum toxins exhibit a high, specific affinity for gangliocide receptors on the surface of presynaptic cholinergic neurons. Receptor mediated endocytosis of tetanus toxin by peripheral cholinergic neurons results in retrograde  
30 axonal transport, blocking of the release of inhibitory neurotransmitters from central synapses and a spastic paralysis. Contrarily, receptor mediated endocytosis of botulinum toxin by peripheral cholinergic

neurons results in little if any retrograde transport, inhibition of acetylcholine exocytosis from the intoxicated peripheral motor neurons and a flaccid paralysis.

5        Finally, the tetanus toxin and the botulinum toxins resemble each other in both biosynthesis and molecular architecture. Thus, there is an overall 34% identity between the protein sequences of tetanus toxin and botulinum toxin type A, and a sequence identity as high as 62% for some functional domains. Binz T. et al., *The Complete Sequence of*  
10 *Botulinum Neurotoxin Type A and Comparison with Other Clostridial Neurotoxins*, J Biological Chemistry 265(16);9153-9158:1990.

### Acetylcholine

Typically only a single type of small molecule neurotransmitter is  
15 released by each type of neuron in the mammalian nervous system, although there is evidence which suggests that several neuromodulators can be released by the same neuron. The neurotransmitter acetylcholine is secreted by neurons in many areas of the brain, but specifically by the large pyramidal cells of the motor cortex, by several  
20 different neurons in the basal ganglia, by the motor neurons that innervate the skeletal muscles, by the preganglionic neurons of the autonomic nervous system (both sympathetic and parasympathetic), by the bag 1 fibers of the muscle spindle fiber, by the postganglionic neurons of the parasympathetic nervous system, and by some of the  
25 postganglionic neurons of the sympathetic nervous system. Essentially, only the postganglionic sympathetic nerve fibers to the sweat glands, the piloerector muscles and a few blood vessels are cholinergic as most of the postganglionic neurons of the sympathetic nervous system secrete the neurotransmitter norepinephrine. In most instances acetylcholine  
30 has an excitatory effect. However, acetylcholine is known to have inhibitory effects at some of the peripheral parasympathetic nerve endings, such as inhibition of heart rate by the vagal nerve.



The efferent signals of the autonomic nervous system are transmitted to the body through either the sympathetic nervous system or the parasympathetic nervous system. The preganglionic neurons of the sympathetic nervous system extend from preganglionic sympathetic neuron cell bodies located in the intermediolateral horn of the spinal cord. The preganglionic sympathetic nerve fibers, extending from the cell body, synapse with postganglionic neurons located in either a paravertebral sympathetic ganglion or in a prevertebral ganglion. Since, the preganglionic neurons of both the sympathetic and parasympathetic nervous system are cholinergic, application of acetylcholine to the ganglia will excite both sympathetic and parasympathetic postganglionic neurons.

Acetylcholine activates two types of receptors, muscarinic and nicotinic receptors. The muscarinic receptors are found in all effector cells stimulated by the postganglionic, neurons of the parasympathetic nervous system as well as in those stimulated by the postganglionic cholinergic neurons of the sympathetic nervous system. The nicotinic receptors are found in the adrenal medulla, as well as within the autonomic ganglia, that is on the cell surface of the postganglionic neuron at the synapse between the preganglionic and postganglionic neurons of both the sympathetic and parasympathetic systems. Nicotinic receptors are also found in many nonautonomic nerve endings, for example in the membranes of skeletal muscle fibers at the neuromuscular junction.

Acetylcholine is released from cholinergic neurons when small, clear, intracellular vesicles fuse with the presynaptic neuronal cell membrane. A wide variety of non-neuronal secretory cells, such as, adrenal medulla (as well as the PC12 cell line) and pancreatic islet cells release catecholamines and parathyroid hormone, respectively, from large

dense-core vesicles. The PC12 cell line is a clone of rat pheochromocytoma cells extensively used as a tissue culture model for studies of sympathoadrenal development. Botulinum toxin inhibits the release of both types of compounds from both types of cells *in vitro*,  
5 permeabilized (as by electroporation) or by direct injection of the toxin into the denervated cell. Botulinum toxin is also known to block release of the neurotransmitter glutamate from cortical synaptosomes cell cultures.

10 A neuromuscular junction is formed in skeletal muscle by the proximity of axons to muscle cells. A signal transmitted through the nervous system results in an action potential at the terminal axon, with activation of ion channels and resulting release of the neurotransmitter acetylcholine from intraneuronal synaptic vesicles, for example at the  
15 motor endplate of the neuromuscular junction. The acetylcholine crosses the extracellular space to bind with acetylcholine receptor proteins on the surface of the muscle end plate. Once sufficient binding has occurred, an action potential of the muscle cell causes specific membrane ion channel changes, resulting in muscle cell contraction.  
20 The acetylcholine is then released from the muscle cells and metabolized by cholinesterases in the extracellular space. The metabolites are recycled back into the terminal axon for reprocessing into further acetylcholine.

25 What is needed therefore is a therapeutically effective method for treating a skin disorder.

### SUMMARY

30 The present invention meets this need and provides methods for effectively treating a skin disorder by local administration of a Clostridial neurotoxin.

A method within the scope of the present invention for treating a skin disorder can have the step of local administration of a Clostridial neurotoxin to a location of a skin disorder of a patient, such as to a face,  
5 hand or foot of a patient. By local administration it is meant that the Clostridial neurotoxin is administered, as by injection, directly to, in, or to the vicinity of, a region of a skin disorder

The neurotoxin can be locally administered in an amount of between  
10 about  $10^{-3}$  units/kg of patient weight and about 35 units/kg of patient weight. Preferably, the neurotoxin is locally administered in an amount of between about  $10^{-2}$  U/kg and about 25 U/kg of patient weight. More preferably, the neurotoxin is administered in an amount of between about  $10^{-1}$  U/kg and about 15 U/kg. In a particularly preferred method  
15 within the scope of the present invention, the neurotoxin is locally administered in an amount of between about 1 U/kg and about 10 U/kg. In a clinical setting it can be advantageous to inject from 1 U to 3000 U of a neurotoxin, such as botulinum toxin type A or B, to a skin disorder location by topical application or by subdermal administration, to  
20 effectively treat the skin disorder.

A suitable neurotoxin for use in the practice of the present invention can be made by a Clostridial bacterium, such as Clostridium botulinum, Clostridium butyricum or Clostridium beratti. The neurotoxin use can be  
25 a modified neurotoxin, that is, a neurotoxin that has had at least one of its amino acids deleted, modified or replaced, as compared to a native neurotoxin. Additionally, the neurotoxin can be recombinantly made produced neurotoxin or a derivative or fragment of a recombinant made neurotoxin. The neurotoxin can be a botulinum toxin, such as one of the  
30 botulinum toxin serotypes A, B, C<sub>1</sub>, D, E, F or G. A preferred botulinum toxin to use in the practice of the present invention is botulinum toxin type A.

A method according to my invention can be carried out by administration of a Clostridial toxin to a patient with, or who is predisposed to, skin disorder. The Clostridial toxin used is preferably a botulinum toxin (as either a complex or as a pure [i.e. about 150 kDa molecule], such as a botulinum toxin A, B, C, D, E, F or G. Administration of the Clostridial toxin can be by a transdermal route (i.e. by application of a Clostridial toxin in a cream, patch or lotion vehicle), subdermal route (i.e. subcutaneous or intramuscular) or intradermal route of administration.

The dose of a Clostridial toxin used according to the present invention is less than the amount of toxin that would be used to paralyze a muscle, since the intent of a method according to the present invention is not to paralyze a muscle but to treat a skin disorder.

The following definitions apply herein:

“About” means approximately or nearly and in the context of a numerical value or range set forth herein means  $\pm 10\%$  of the numerical value or range recited or claimed.

“Alleviating” means a reduction in the occurrence of a skin disorder symptom. Thus, alleviating includes some reduction, significant reduction, near total reduction, and total reduction of a skin disorder symptom. An alleviating effect may not appear clinically for between 1 to 7 days after administration of a Clostridial neurotoxin to a patient.

“Botulinum toxin” means a botulinum neurotoxin as either pure toxin (i.e. about 150 kDa weight molecule) or as a complex (i.e. about 300 to about 900 kDa weight complex comprising a neurotoxin molecule and one or more associated non-toxic molecules), and excludes botulinum

toxins which are not neurotoxins such as the cytotoxic botulinum toxins C2 and C3, but includes recombinantly made, hybrid, modified, and chimeric botulinum toxins.

5        "Local administration" or "locally administering" means administration (i.e. by a subcutaneous, intramuscular, subdermal or transdermal route) of a pharmaceutical agent to or to the vicinity of a dermal or subdermal location of a patient.

10        "Skin disorder" means a localized skin abnormality which can be a skin growth such as a wart, corn, callus or mole.

"Treating" means to alleviate (or to eliminate) at least one symptom of a skin disorder, either temporarily or permanently.

15

The Clostridial neurotoxin is administered in a therapeutically effective amount to alleviate a symptom of a skin disorder. A suitable Clostridial neurotoxin may be a neurotoxin made by a bacterium, for example, the neurotoxin may be made from a *Clostridium botulinum*,  
20    *Clostridium butyricum*, or *Clostridium beratti*. In certain embodiments of the invention, the skin disorder can be treated by applying to (topical) or into (intra or transdermal) the skin of a patient a botulinum toxin. The botulinum toxin can be a botulinum toxin type A, type B, type C1, type D, type E, type F, or type G. The skin disorder alleviating effects of the  
25    botulinum toxin may persist for between about 2 weeks (i.e. upon administration of a short acting botulinum toxin, such as a botulinum toxin type E) and 5 years (i.e. upon implantation of a controlled release botulinum toxin implant). The botulinum neurotoxin can be a recombinantly made botulinum neurotoxins, such as botulinum toxins  
30    produced by an E. coli bacterium. In addition or alternatively, the botulinum neurotoxin can be a modified neurotoxin, that is a botulinum neurotoxin which has at least one of its amino acids deleted, modified or

replaced, as compared to a native or the modified botulinum neurotoxin can be a recombinant produced botulinum neurotoxin or a derivative or fragment thereof.

5       A method for treating a skin disorder according to the present invention can comprise the step of local administration of a botulinum toxin to a patient with a skin disorder to thereby alleviate the skin disorder. The botulinum toxin can be selected from the group consisting of botulinum toxin types A, B, C, D, E, F and G. Botulinum toxin type A  
10       is a preferred botulinum toxin.

      A detailed embodiment of my invention can comprise a method for treating a skin disorder by local administration to a patient with a skin disorder of between about 1 unit and about 3,000 units of a botulinum  
15       toxin (for example between about 1-50 units of a botulinum toxin type A or between about 50 to 3,000 units of a botulinum toxin type B), thereby alleviating the skin disorder for between about two weeks and about 5 years.

20       My invention also encompasses a method for treating skin disorder by locally administering a botulinum toxin (such as a botulinum toxin type A, B, C, D, E, F or G, in an amount of from 1 unit to 3,000 units per treatment session) to a patient predisposed to experience skin disorder, thereby preventing the patient from experiencing a skin disorder. A  
25       patient predisposed to skin disorder is a human who has experienced skin disorder at least once within the last twelve months. The local administration can be carried out by subcutaneous or by topical administration of the botulinum toxin a location on or within the skin of the patient where a skin disorder is located. The skin disorder can be  
30       reduced in size by from about 20% to 100%.

## DESCRIPTION

The present invention is based upon the discovery that a skin  
5 disorder can be treated by local administration of a therapeutically  
effective amount of a Clostridial neurotoxin, such as a botulinum  
neurotoxin. The botulinum neurotoxin (such as a botulinum neurotoxin  
serotype A, B, C, D, E, F or G) can be injected into or topically applied  
10 onto or in the vicinity of a skin disorder of a patient. Alternately, the  
botulinum toxin can be administered to an intradermal or subdermal  
neuron to thereby downregulate, inhibit or suppress a neuronally  
mediated or influenced skin disorder.

Without wishing to be bound by theory a physiological mechanism  
15 can be proposed for the efficacy of my invention as disclosed herein for  
the treatment of a skin disorder using a Clostridial neurotoxin.  
Essentially, it is hypothesized that use of a botulinum toxin can inhibit  
release of acetylcholine and/or of another neurotransmitter or  
neuropeptide by one or more dermal nerves or structures which  
20 innervate or which influence a skin disorder, to thereby permit effective  
treatment of a skin disorder. Alternately, the administered Clostridial  
neurotoxin may have a direct effect upon the skin disorder. By effective  
treatment it is meant that the skin disorder becomes less painful, less  
inflamed and/or regresses (i.e. becomes smaller in size [i.e. thinner] or  
25 disappears altogether).

With regard to a proposed physiological mechanism for use of a  
Clostridial neurotoxin to treat a skin disorder as set forth herein, it is  
known that human keratinocytes can respond to acetylcholine. It is  
30 believed that acetylcholine is released by keratinocytes to function as a  
local hormone in the epidermis. Grando S. et al., *Human keratinocytes  
synthesize, secrete, and degrade acetylcholine*, J Invest Dermatol. 1993

Jul;101(1):32-6. Human epidermal keratinocytes possess cholinergic enzymes, which synthesize and degrade acetylcholine, and express both nicotinic and muscarinic classes of cholinergic receptors on their cell surfaces. These epidermal keratinocyte cell surface receptors bind  
5 acetylcholine and initiate various cellular responses. Significantly, the presence in keratinocytes of a functional cholinergic system suggests a role for acetylcholine in most, if not all, aspects of keratinocyte function. Acetylcholine employs calcium as a mediator for its effects on keratinocytes. In turn, changes in calcium concentration can affect  
10 expression and function of keratinocyte cholinergic enzymes and cholinergic receptors. At different stages of their differentiation, keratinocytes demonstrate unique combinations of cholinergic enzymes and cholinergic receptor types. Grando S., *Biological functions of keratinocyte cholinergic receptors*, J Investig Dermatol Symp Proc. 1997  
15 Aug;2(1):41-8.

Importantly, skin innervation exerts influence on the proliferation of keratinocytes and the thickness of the epidermis. *Huang et al., Influence of cutaneous nerves on keratinocyte proliferation and*  
20 *epidermal thickness in mice. Neuroscience. 1999;94(3):965-73.* Several lines of evidence suggest that nerves which terminate in the skin have profound influences on their target, the epidermis. See e.g. Grando S., *Biological functions of keratinocyte cholinergic receptors*, J Investig Dermatol Symp Proc. 1997 Aug;2(1):41-8; Grando S., et al., *Activation*  
25 *of keratinocyte nicotinic cholinergic receptors stimulates calcium influx and enhances cell differentiation.* Invest Dermatol. 1996 Sep;107(3):412-8; Ndoye A., et al., *Identification and mapping of keratinocyte muscarinic acetylcholine receptor subtypes in human epidermis*, J Invest Dermatol. 1998 Sep;111(3):410-6; Palacios J., et al.,  
30 *Cholinergic neuropharmacology: an update*, Acta Psychiatr Scand Suppl. 1991;366:27-33; Whitehouse P., et al., *Nicotinic and muscarinic cholinergic receptors in Alzheimer's disease and related disorders*, J



Neural Transm Suppl. 1987;24:175-82; Arredondo J., et al., *Central role of alpha7 nicotinic receptor in differentiation of the stratified squamous epithelium*, J Cell Biol. 2002 Oct 28;159(2):325-36; Andreadis S., et al., *Keratinocyte growth factor induces hyperproliferation and delays differentiation in a skin equivalent model system*, FASEB J. 2001 Apr;15(6):898-906; Krnjevic K., *Central cholinergic mechanisms and function*. Prog Brain Res. 1993;98:285-92; *Epidermal expression of the full-length extracellular calcium-sensing receptor is required for normal keratinocyte differentiation*, J Cell Physiol. 2002 Jul;192(1):45-54;

5      Grando S., et al., *Human keratinocytes synthesize, secrete, and degrade acetylcholine* J Invest Dermatol. 1993 Jul;101(1):32-6; Zia S., et al., *Receptor-mediated inhibition of keratinocyte migration by nicotine involves modulations of calcium influx and intracellular concentration*, J Pharmacol Exp Ther. 2000 Jun;293(3):973-81; Nguyen V., et al.,

10      *Keratinocyte acetylcholine receptors regulate cell adhesion* Life Sci. 2003 Mar 28;72(18-19):2081-5; Nguyen V., et al., *Programmed cell death of keratinocytes culminates in apoptotic secretion of a humectant upon secretagogue action of acetylcholine* J Cell Sci. 2001 Mar;114(Pt 6):1189-204; Grando S., et al., *Keratinocyte muscarinic acetylcholine*

15      *receptors: immunolocalization and partial characterization*, J Invest Dermatol. 1995 Jan;104(1):95-100; Lin Y., et al., (2001) *Cutaneous nerve terminal degeneration in painful mononeuropathy*, Experimental Neurology. 170(2):290-6; Pan C., et al., (2001) *Degeneration of nociceptive nerve terminals in human peripheral neuropathy*,

20      Neuroreport. 12(4):787-92; Hsiung-F., et al., (2001) *Quantitative pathology of cutaneous nerve terminal degeneration in the human skin*, Acta Neuropathologica 102:455-461; Ko M., et al., *Cutaneous nerve degeneration induced by acrylamide in mice*, Neuroscience Letters.(2000)293(3):195-8; Lin Y., et al., *Quantitative sensory testing: normative*

25      *values and its application in diabetic neuropathy*, Acta Neurol Taiwan 1998;7:176-184; T. Huang, et al., *Influence of cutaneous nerves on keratinocyte proliferation and epidermal thickness in mice*,

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Neuroscience 94 :965-973, 1999; Hsieh S., et al., *Pathology of nerve terminal degeneration in the skin*, Journal of Neuropathology & Experimental Neurology. 2000;59(4):297-307; Huang I. et al., *Influence of cutaneous nerves on keratinocyte proliferation and epidermal thickness in mice*, Neuroscience. 1999;94(3):965-73; Hsieh S., et al., *Modulation of keratinocyte proliferation by skin innervation*. Journal of Investigative Dermatology, 1999;113(4):579-86; Chen W., et al., *Trophic interactions between sensory nerves and their targets*, Journal of Biomedical Science. 1999;6(2):79-85; Chiang H-Y, et al., *Regional difference in epidermal thinning after skin denervation*, Exp Neurol 1998;154(1):137-45; Hsieh S., et al., *Skin innervation and its influence on the epidermis*, J Biomed Sci 1997;4:264-268; Lee M., et al., *Clinical and electrophysiological characteristics of inflammatory demyelinating neuropathies*, Acta Neurol Taiwan 1997;6:283-288; Wu T., et al., *Demonstration of human papillomavirus (HPV) genomic amplification and viral-like particles from CaSki cell line in SCID mice*, J Virol Methods 1997;65:287-298; Hsieh S., et al., *Epidermal denervation and its effects on keratinocytes and Langerhans cells*, J Neurocytol 1996;25:513-524; McCarthy B., et al., *Cutaneous innervation in sensory neuropathies: evaluation by skin biopsy*, Neurol 1995;45:1848-1855; Griffin J., et al., *Axonal degeneration and disorders of the axonal cytoskeleton*. In: Waxman S., et al., The Axon. New York: Oxford University Press, 1995:375-390.

Thus, it can be postulated that a botulinum toxin can be used to induce denervation and thereby can treat a skin disorder - by preventing (i.e. downregulating) the release of various neuropeptides released by nerves which innervate the skin. Among these neuropeptides are the tachykinins, substance P and neurokinin A, calcitonin gene-related peptide (CGRP), vasoactive intestinal peptide (VIP) and somatostatin, all of which have been reported to modulate skin cell functions such as cell proliferation. As set forth previously, release of most

neurotransmitters and related neuropeptides can be blocked by botulinum toxin. See e.g. Hokfelt T., *Neuropeptides in perspective : The last ten years*, Neuron 1991; 7: 867-879; Xu Z-QD et al, *Galanin/GMAP- and NPY-like immunoreactivities in locus coeruleus and noradrenergic nerve terminals in the hippocampal formation and cortex with notes on the galanin-R1 and - R2 receptors*, J. Comp. Neurol. 1998; 392: 227-252; Xu Z-QD et al, *Galanin-5-hydroxytryptamine interactions: Electrophysiological, immunohistochemical and in situ hybridization studies on rat dorsal raphe neurons with a note on galanin R1 and R2 receptors*. Neuroscience 1998; 87: 79-94; Johnson M., *Synaptic glutamate release by postnatal rat serotonergic neurons in microculture*, Neuron 1994; 12: 433-442; Sneddon P., et al., *Pharmacological evidence that adenosine triphosphate and noradrenaline are cotransmitters in the guinea-pig vas deferens*. J. Physiol. 1984; 347: 561-580; Kaneko T., et al., *Immunohistochemical demonstration of glutaminase in catecholaminergic and serotonergic neurons of rat brain*, Brain Res. 1990; 507: 141-154; Kasakov L., et al., *Direct evidence for concomitant release of noradrenaline, adenosine 5'-triphosphate and neuropeptide Y from sympathetic nerve supplying the guinea-pig vas deferens*. J. Auton. Nerv. Syst. 1988; 22: 75-82; Nicholas A. et al., *Glutamate-like immunoreactivity in medulla oblongata catecholamine/substance P neurons*, NeuroReport 1990; 1: 235-238; Nicholas A. et al., Kupfermann I., *Functional studies of cotransmission*. Physiol. Rev. 1991; 71: 683-732.48: 545-59; Lundberg J., *Pharmacology of cotransmission in the autonomic nervous system: Integrative aspects on amines, neuropeptides, adenosine triphosphate, amino acids and nitric oxide*, Pharmacol. Rev. 1996; 48: 113-178; Hsieh S., et al., *Skin Innervation and Its Effects on the Epidermis*, J Biomed Sci. 1997;4(5):264-268; Legat F., et al., *Repeated subinflammatory ultraviolet B irradiation increases substance P and calcitonin gene-related peptide content and augments mustard oil-induced neurogenic inflammation in the skin of rats*, Neurosci Lett. 2002 Sep 6;329(3):309-

13; White S., et al., Asahina A., et al., *Specific induction of cAMP in Langerhans cells by calcitonin gene-related peptide: relevance to functional effects*, Proc Natl Acad Sci U S A. 1995 Aug 29;92(18):8323-7; Inaba N., et al., *Capsaicin-induced calcitonin gene-related peptide release from isolated rat stomach measured with a new chemiluminescent enzyme immunoassay*, Jpn J Pharmacol. 1996 Nov;72(3):223-9; Hosoi J., et al., *Regulation of Langerhans cell function by nerves containing calcitonin gene-related peptide*, Nature. 1993 May 13;363(6425):159-63.

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Figure 1 illustrates a mechanism of action of a botulinum toxin ("Btx" in Figure 1). A botulinum toxin can inhibit release of cGRP, SP, and glutamate from dermal sensory nerves, and also inhibit direct release of these mediators from skin keratinocyte, endothelial and melanocyte cells. It is known that neuropeptides released by sensory nerves that innervate the skin and contact epidermal and dermal cells can directly modulate functions of keratinocytes, Langerhans cells (LC), mast cells, dermal microvascular endothelial cells and infiltrating immune cells. In Figure 1 NO is nitrous oxide, cGRP is calcitonin gene-related peptide, Ach is acetylcholine, cGRP-R is the receptor for the cGRP molecule, v-dil means vasodilatation and SP is substance P.

Furthermore, it has been demonstrated that denervation of the skin can cause the epidermis to began to degenerate or to become thinner. Hsieh S., et al., *Modulation of keratinocyte proliferation by skin innervation*, J Invest Dermatol. 1999 Oct;113(4):579-86; Hsieh S., et al., *Epidermal denervation and its effects on keratinocytes and Langerhans cells*, J Neurocytol. 1996 Sep;25(9):513-24.; Chiang, et al., *Regional difference in epidermal thinning after skin denervation*, Exp Neurol 1998 Nov;154(1):137-45; Li Y., et al., *Sensory and motor denervation influence epidermal thickness in rat foot glabrous skin*, Exp Neurol. 1997 Oct;147(2):452-62 (botulinum toxin blockade caused epidermal

thickness to be significantly reduced in the central area of the sole of the rat foot).

My invention encompasses methods for treating a skin growth. A  
5 skin growth can result in pain and/or inflammation at the skin growth location. Notably, a skin growth can occur in a patient who is not a candidate for an invasive therapy, such as surgery in a diabetic patient. Thus, my invention includes use of a botulinum toxin to treat a skin  
10 growth by causing it to regress (become smaller) and/or to relieve the pain and inflammation that can accompany a skin disorder, such as a bunion, callus, neuroma, ulcer, warts, corn, or hammertoe.

The amount of the Clostridial toxin administered according to a method within the scope of the disclosed invention can vary according to  
15 the particular characteristics of the skin disorder being treated, including its severity and other various patient variables including size, weight, age, and responsiveness to therapy. To guide the practitioner, typically, no less than about 1 unit and no more than about 50 units of a botulinum toxin type A (such as BOTOX®) is administered per injection  
20 site (i.e. to each skin disorder location injected), per patent treatment session. For a botulinum toxin type A such as DYSPORT®, no less than about 2 units and no more about 200 units of the botulinum toxin type A are administered per administration or injection site, per patent treatment session. For a botulinum toxin type B such as MYOBLOC®,  
25 no less than about 40 units and no more about 2500 units of the botulinum toxin type B are administered per administer or injection site, per patent treatment session. Less than about 1, 2 or 40 units (of BOTOX®, DYSPORT® and MYOBLOC® respectively) can fail to achieve a desired therapeutic effect, while more than about 50, 200 or  
30 2500 units (of BOTOX®, DYSPORT® and MYOBLOC® respectively) can result in clinically observable and undesired muscle hypotonicity, weakness and/or paralysis.

More preferably: for BOTOX® no less than about 2 units and no more about 20 units of a botulinum toxin type A; for DYSPORT® no less than about 4 units and no more than about 100 units, and; for  
5 MYOBLOC®, no less than about 80 units and no more than about 1000 units are, respectively, administered per injection site, per patent treatment session.

Most preferably: for BOTOX® no less than about 5 units and no  
10 more about 15 units of a botulinum toxin type A; for DYSPORT® no less than about 20 units and no more than about 75 units, and; for MYOBLOC®, no less than about 200 units and no more than about 750 units are, respectively, administered per injection site, per patent treatment session. It is important to note that there can be multiple  
15 injection sites (i.e. a pattern of injections) for each patient treatment session.

Although examples of routes of administration and dosages are provided, the appropriate route of administration and dosage are  
20 generally determined on a case by case basis by the attending physician. Such determinations are routine to one of ordinary skill in the art (see for example, *Harrison's Principles of Internal Medicine* (1998), edited by Anthony Fauci et al., 14th edition, published by McGraw Hill). For example, the route and dosage for administration of a Clostridial  
25 neurotoxin according to the present disclosed invention can be selected based upon criteria such as the solubility characteristics of the neurotoxin chosen as well as the intensity and scope of a skin disorder.

The present invention is based on the discovery that local  
30 administration of a Clostridial toxin can provide significant and long

lasting relief from a skin disorder. A Clostridial toxin used in accordance with the invention disclosed herein can inhibit transmission of chemical or electrical signals between select neuronal groups that are involved in generation of a skin disorder. The Clostridial toxins preferably are not  
5 cytotoxic to the cells that are exposed to the Clostridial toxin. The Clostridial toxin can inhibit neurotransmission by reducing or preventing exocytosis of neurotransmitter from the neurons exposed to the Clostridial toxin. Or the applied Clostridial toxin can reduce neurotransmission by inhibiting the generation of action potentials of the  
10 neurons exposed to the toxin. The skin disorder alleviation effect provided by the Clostridial toxin can persist for a relatively long period of time, for example, for more than two months, and potentially for several years.

15 Examples of Clostridial toxins within the scope of the present invention include neurotoxins made by *Clostridium botulinum*, *Clostridium butyricum* and *Clostridium beratti* species. In addition, the botulinum toxins used in the methods of the invention may be a botulinum toxin selected from a group of botulinum toxin types A, B, C,  
20 D, E, F, and G. In one embodiment of the invention, the botulinum neurotoxin administered to the patient is botulinum toxin type A. Botulinum toxin type A is desirable due to its high potency in humans, ready availability, and known use for the treatment of skeletal and smooth muscle disorders when locally administered by intramuscular  
25 injection. The present invention also includes the use of (a) Clostridial neurotoxins obtained or processed by bacterial culturing, toxin extraction, concentration, preservation, freeze drying, and/or reconstitution; and/or (b) modified or recombinant neurotoxins, that is neurotoxins that have had one or more amino acids or amino acid  
30 sequences deliberately deleted, modified or replaced by known chemical/biochemical amino acid modification procedures or by use of known host cell/recombinant vector recombinant technologies, as well

as derivatives or fragments of neurotoxins so made. These neurotoxin variants retain the ability to inhibit neurotransmission between or among neurons, and some of these variants may provide increased durations of inhibitory effects as compared to native neurotoxins, or may provide enhanced binding specificity to the neurons exposed to the neurotoxins. These neurotoxin variants may be selected by screening the variants using conventional assays to identify neurotoxins that have the desired physiological effects of inhibiting neurotransmission.

Botulinum toxins for use according to the present invention can be stored in lyophilized, vacuum dried form in containers under vacuum pressure or as stable liquids. Prior to lyophilization the botulinum toxin can be combined with pharmaceutically acceptable excipients, stabilizers and/or carriers, such as albumin. The lyophilized material can be reconstituted with saline or water to create a solution or composition containing the botulinum toxin to be administered to the patient.

Although the composition may only contain a single type of neurotoxin, such as botulinum toxin type A, as the active ingredient to suppress neurotransmission, other therapeutic compositions may include two or more types of neurotoxins, which may provide enhanced therapeutic treatment of a skin disorder. For example, a composition administered to a patient may include botulinum toxin type A and botulinum toxin type B. Administering a single composition containing two different neurotoxins can permit the effective concentration of each of the neurotoxins to be lower than if a single neurotoxin is administered to the patient while still achieving the desired therapeutic effects. The composition administered to the patient may also contain other pharmaceutically active ingredients, such as, protein receptor or ion channel modulators, in combination with the neurotoxin or neurotoxins. These modulators may contribute to the reduction in neurotransmission



between the various neurons. For example, a composition may contain gamma aminobutyric acid (GABA) type A receptor modulators that enhance the inhibitory effects mediated by the GABAA receptor. The GABAA receptor inhibits neuronal activity by effectively shunting current  
5 flow across the cell membrane. GABAA receptor modulators may enhance the inhibitory effects of the GABAA receptor and reduce electrical or chemical signal transmission from the neurons. Examples of GABAA receptor modulators include benzodiazepines, such as diazepam, oxaxepam, lorazepam, prazepam, alprazolam, halazeapam,  
10 chordiazepoxide, and chlorazepate. Compositions may also contain glutamate receptor modulators that decrease the excitatory effects mediated by glutamate receptors. Examples of glutamate receptor modulators include agents that inhibit current flux through AMPA, NMDA, and/or kainate types of glutamate receptors. The compositions  
15 may also include agents that modulate dopamine receptors, such as antipsychotics, norepinephrine receptors, and/or serotonin receptors. The compositions may also include agents that affect ion flux through voltage gated calcium channels, potassium channels, and/or sodium channels. Thus, the compositions used to treat a skin disorder can  
20 include one or more neurotoxins, such as botulinum toxins, in addition to ion channel receptor modulators that may reduce neurotransmission.

The neurotoxin may be administered by any suitable method as determined by the attending physician. The methods of administration  
25 permit the neurotoxin to be administered locally to a selected target tissue. Methods of administration include injection of a solution or composition containing the neurotoxin, as described above, and include implantation of a controlled release system that controllably releases the neurotoxin to the target tissue. Such controlled release systems reduce  
30 the need for repeat injections. Diffusion of biological activity of a botulinum toxin within a tissue appears to be a function of dose and can be graduated. Jankovic J., et al *Therapy With Botulinum Toxin*, Marcel

Dekker, Inc., (1994), page 150. Thus, diffusion of botulinum toxin can be controlled to reduce potentially undesirable side effects that may affect the patient's cognitive abilities. For example, the neurotoxin can be administered so that the neurotoxin primarily effects neural systems  
5 believed to be involved in the generation of a skin disorder.

A polyanhydride polymer, Gliadel® (Stollé R & D, Inc., Cincinnati, OH) a copolymer of poly-carboxyphenoxypropane and sebacic acid in a ratio of 20:80 has been used to make implants, and has been  
10 intracranially implanted to treat malignant gliomas. Polymer and BCNU can be co-dissolved in methylene chloride and spray-dried into microspheres. The microspheres can then be pressed into discs 1.4 cm in diameter and 1.0 mm thick by compression molding, packaged in aluminum foil pouches under nitrogen atmosphere and sterilized by 2.2  
15 megaRads of gamma irradiation. The polymer permits release of carmustine over a 2-3 week period, although it can take more than a year for the polymer to be largely degraded. Brem, H., et al, *Placebo-Controlled Trial of Safety and Efficacy of Intraoperative Controlled Delivery by Biodegradable Polymers of Chemotherapy for Recurrent Gliomas*, Lancet 345;1008-1012:1995.  
20

Implants useful in practicing the methods disclosed herein may be prepared by mixing a desired amount of a stabilized neurotoxin (such as non-reconstituted BOTOX®) into a solution of a suitable polymer  
25 dissolved in methylene chloride. The solution may be prepared at room temperature. The solution can then be transferred to a Petri dish and the methylene chloride evaporated in a vacuum desiccator. Depending upon the implant size desired and hence the amount of incorporated neurotoxin, a suitable amount of the dried neurotoxin incorporating  
30 implant is compressed at about 8000 p.s.i. for 5 seconds or at 3000 p.s.i. for 17 seconds in a mold to form implant discs encapsulating the neurotoxin. See e.g. Fung L. K. et al., *Pharmacokinetics of Interstitial*

*Delivery of Carmustine 4-Hydroperoxycyclophosphamide and Paclitaxel  
From a Biodegradable Polymer Implant in the Monkey Brain, Cancer  
Research 58;672-684:1998.*

5        Local administration of a Clostridial toxin, such as a botulinum toxin,  
can provide a high, local therapeutic level of the toxin. A controlled  
release polymer capable of long term, local delivery of a Clostridial toxin  
to a target skin disorder location permits effective dosing of the target  
tissue. A suitable implant, as set forth in U.S. patent number 6,306,423  
10    entitled "Neurotoxin Implant", allows the direct introduction of a  
chemotherapeutic agent to a target tissue via a controlled release  
polymer. The implant polymers used are preferably hydrophobic so as  
to protect the polymer incorporated neurotoxin from water induced  
decomposition until the toxin is released into the target tissue  
15    environment.

Local administration of a botulinum toxin, according to the present  
invention, by injection or implant to a target tissue provides a superior  
alternative to systemic administration of pharmaceuticals to patients to  
20    alleviate a skin disorder.

The amount of a Clostridial toxin selected for local administration to a  
target tissue according to the present disclosed invention can be varied  
based upon criteria such as the severity of the skin disorder being  
25    treated, solubility characteristics of the neurotoxin toxin chosen as well  
as the age, sex, weight and health of the patient. For example, the  
extent of the area of skin influenced is believed to be proportional to the  
volume of neurotoxin injected, while the quantity of the skin disorder  
suppressant effect is, for most dose ranges, believed to be proportional  
30    to the concentration of a Clostridial toxin administered. Methods for  
determining the appropriate route of administration and dosage are  
generally determined on a case by case basis by the attending

physician. Such determinations are routine to one of ordinary skill in the art (see for example, *Harrison's Principles of Internal Medicine* (1998), edited by Anthony Fauci et al., 14th edition, published by McGraw Hill).

5           Significantly, a method within the scope of the present invention can provide improved patient function. "Improved patient function" can be defined as an improvement measured by factors such as a reduced pain, reduced time spent in bed, increased ambulation, healthier attitude, more varied lifestyle and/or healing permitted by normal muscle  
10   tone. Improved patient function is synonymous with an improved quality of life (QOL). QOL can be assessed using, for example, the known SF-12 or SF-36 health survey scoring procedures. SF-36 assesses a patient's physical and mental health in the eight domains of physical functioning, role limitations due to physical problems, social functioning,  
15   bodily pain, general mental health, role limitations due to emotional problems, vitality, and general health perceptions. Scores obtained can be compared to published values available for various general and patient populations.

20 EXAMPLES

The following non-limiting examples provide those of ordinary skill in the art with specific preferred methods to treat conditions within the scope of the present invention and are not intended to limit the scope of the invention. In the following examples various modes of non-systemic administration of a Clostridial neurotoxin can be carried out. For example, by topical application (cream or transdermal patch), subcutaneous injection, or by implantation of a controlled release implant.

Example 1  
Use of a Botulinum Toxin to Treat a Bone Spur

A 61 year old diabetic female presents with a pain that has developed at the bottom of her heel, and it has gotten worse. The patient is not aware of having had any injury that caused it. The patient is diagnosed with a painful bone spur at the center of the left heel. She reports a dull ache most of the time, but when the patient first gets out of the bed in the morning, or when getting up after sitting for a period of time during the day, the pain in the heel is almost unbearable, felling like the heel has been bruised, from falling on a rock barefoot, but it is worse. Several therapies including topical lidocaine, NSAIDS, and therapy are tried with little relief. Surgery is not an option due to the poor blood circulation of the patient's lower limbs. Therefore, botulinum toxin type A as 30 units total can be applied following use of a topical anesthetic, 10U/site in three subcutaneous injection sites spaced evenly apart over the painful area. On follow-up 2 weeks later, the patient can report significant relief of pain and can tolerate walking. Four weeks later the patient can reported no pain and be able to tolerate walking greater distances than two weeks earlier.

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Example 2  
Use of a Botulinum Toxin to Treat Corns and Bunions

A 54 year old male who has been walking extensively at a large amusement park for three days with his grandchildren, reports significant pain on the proximal right side of his great toe, and on the plantar side of the foot pad on the same foot. The pain can become excruciating and debilitating. The patient has had a history of painful corns and bunions on both feet, which are recurrent, despite medical and orthotic treatment. Upon examination, a 6 cm<sup>2</sup> growth consistent with a corn and a 8 cm<sup>2</sup> circular, inflamed area on the plantar side, consistent with a bunion, is noted. A treatment with a botulinum toxin type A can be commenced as 50U of toxin injected (2 sites/25U each) intradermally into the corn and 30U into the bunion. 14 days later, the

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patient can report significant relief in both affected areas. Two months later, the patient can report a reduction of over 50% in the size of the corn and 60% of the size of the bunion, with no pain. The patient can be able to return to normal walking activities and can also tolerate walking great distances.

### Example 3

#### Use of a Botulinum Toxin to Treat Genital Warts

A 48 year old female presents with a history of genital warts.

Examination of the patient reveals six flesh-colored bumps or tiny, cauliflower-like maculopapular warts of various sizes ( $0.05 \text{ cm}^2$  to  $2 \text{ cm}^2$ ). The patient had been treated with several different treatment methods; direct application of bleomycin, acetylsilic acid, with little or no relief. The patient refuses laser or other types of invasive methods of treatments. A botulinum toxin type A is applied directly into the wart areas via intra-dermal injection, in an effective amount of, but not limited to  $5\text{U}/\text{cm}^2$ , for a total of 30U. Upon follow up 4 weeks later, 3 of the smaller warts, can have disappeared completely and at 2 months, the patient can report disappearance of the remaining warts.

### Example 4

#### Use of a Botulinum Toxin to Treat Plantar Warts

A 54 year old male has a history of painful plantar warts and returns to the clinic following an exacerbation of wart growth on the plantar region of his right foot. Upon examination, 3 various sized warts ( $1 \text{ cm}^2$ ,  $2.5 \text{ cm}^2$  and  $4.4 \text{ cm}^2$ ), with a rubor colored ring surrounding 2 of the 3 warts, suggesting inflammation,. Patient has tried in bleomycin but relief was minimal and caused significant pain following injection. Therefore, a botulinum neurotoxin is considered as an alternative and  $5\text{U}/\text{cm}^2$  can be applied in a topical formulation directly to the wart for a total of 45U. On follow up 2 months later, the patient can report complete relief of pain and upon examination, there were no signs of inflammation (rubor

rings not present), and 2 of the 3 warts had disappeared completely with only ~ 1 cm<sup>2</sup> of the 4.4 cm<sup>2</sup> wart visible.

In each of the examples above a botulinum toxin type B, C, D, E, F or  
5 G can be substituted for the botulinum toxin type A used above, for  
example by use of 250 units of a botulinum toxin type B. The specific  
amount of a botulinum toxin (such as BOTOX® administered depends  
upon a variety of factors to be weighed and considered within the  
discretion of the attending physician and in each of the examples  
10 insignificant amounts of botulinum toxin enter appear systemically with  
no significant side effects.

A method for treating a skin disorder according to the invention  
disclosed herein has many benefits and advantages, including the  
15 following:

1. the symptoms of a skin disorder can be dramatically reduced or  
eliminated.
- 20 2. the symptoms of a skin disorder can be reduced or eliminated for  
at least about two weeks to about six months per injection of neurotoxin  
and for from about one year to about five years upon use of a controlled  
release neurotoxin implant.
- 25 3. the injected or implanted Clostridial neurotoxin shows little or no  
tendency to diffuse or to be transported away from the intramuscular (or  
intra dermal or subdermal) injection or implantation site.
4. few or no significant undesirable side effects occur from  
30 intramuscular (or intra dermal or subdermal) injection or implantation of  
the Clostridial neurotoxin.

5. the present methods can result in the desirable side effects of greater patient mobility, a more positive attitude, and an improved quality of life.

5        Although the present invention has been described in detail with regard to certain preferred methods, other embodiments, versions, and modifications within the scope of the present invention are possible. For example, a wide variety of neurotoxins can be effectively used in the methods of the present invention. Additionally, the present invention  
10 includes local administration methods to alleviate a skin disorder wherein two or more neurotoxins, such as two or more botulinum toxins, are administered concurrently or consecutively. For example, botulinum toxin type A can be administered until a loss of clinical response or neutralizing antibodies develop, followed by administration of botulinum  
15 toxin type B. Alternately, a combination of any two or more of the botulinum serotypes A-G can be locally administered to control the onset and duration of the desired therapeutic result. Furthermore, non-neurotoxin compounds can be administered prior to, concurrently with or subsequent to administration of the neurotoxin to provide adjunct effect  
20 such as enhanced or a more rapid onset of denervation before the neurotoxin, such as a botulinum toxin, begins to exert its therapeutic effect.

      A botulinum toxin can be administered by itself or in combination of  
25 one or more of the other botulinum toxin serotypes. The botulinum toxin can be a recombinantly made or a hybrid botulinum toxin.

      My invention also includes within its scope the use of a neurotoxin, such as a botulinum toxin, in the preparation of a medicament for the  
30 treatment of a skin disorder, by local administration of the neurotoxin.



All references, articles, patents, applications and publications set forth above are incorporated herein by reference in their entireties.

Accordingly, the spirit and scope of the following claims should not  
5 be limited to the descriptions of the preferred embodiments set forth  
above.